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Plastic Deformation and Fracture of Steel

Under Dynamic Loading

LEVEL II

Final Report

J. Duffy

September, 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The author summarizes his research effort during the grant period. Included is the development of an infrared radiation temperature detection system for monitoring the temperature rise in thin-walled steel specimens loaded dynamically in a torsional Kolsky bar. Also included is a description of an investigation aimed at transforming AISI 1020 HRS under controlled conditions of prior austenite grain size, ferrite and pearlite grain sizes to reduce the size and number of carbide plates along the grain boundaries. The transformed material is to be used in a subsequent investigation into the influence of microstructure on the fracture toughness of 1020 HRS.

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Plastic Deformation and Fracture of Steel Under Dynamic Loading

During the one-year period of this grant we have advanced our continuing studies into the formation of shear bands in AISI 1018 cold rolled steel (CRS) and in determining the source of dynamic fracture initiation in 1020 hot rolled steel (HRS) on the lower shelf.

The shear band investigation concentrated on the measurement of the temperature of thin-walled tubular specimens subjected to a dynamic stress pulse in a torsional Kolsky bar while a shear band is forming within the specimen. Our earlier work utilized a single indiumantimonide infrared radiation detector to sense the specimen's temperature rise. During this grant period we concentrated on the development of a multiple detector temperature sensing system that will provide a means for recording the temperature profile along the entire specimen gage length as the shear band is forming. All components of a 12-element detection system have been purchased or assembled with the exception of the 12-element detector which is due to be shipped soon. All other system components have been tested. In addition, some exploratory experiments aimed at producing shear bands in AISI 4340 steel have been performed using specimens of widely varying tempers. The specimens thus tested range from quite brittle to ductile and shear bands were produced in many of them. Upon continued straining, many of the shear bands have led to (mode II) fractures. This last phenomenon is of considerable interest since an understanding of the processes which lead to fracture have a wide variety of practical applications. This work will continue under the current multidisciplinary grant from ARO to Brown University and will include a series of experiments in which the length of the imposed stress pulse will gradually be decreased to reduce the total strain (at the same strain rate). By microscopic examination of the specimens we wish to study the initiation of fracture within the shear band.

In collaboration with Professor R. J. Asaro, we recently initiated an investigation into the influence of microstructure on the fracture toughness of 1020 HRS. While other investigators have presented thorough analyses of fracture in low carbon steels, on the one hand, and of pearlitic eutectoid steels, on the other, much work remains to be done for steels in the hypo-eutectoid range. In a preliminary investigation we had attempted to determine the role during brittle fracture of the carbide plates which lie along the ferrite grain boundaries in 1020 HRS. This preliminary work considered only the effects of a change in the carbide plate size and their number on fracture toughness, but our subsequent microscopic examination of the fractured specimens showed a fairly wide range of prior austenite and ferrite grain sizes which may have influenced our early results. This has led us into a detailed study of the fracture process taking into consideration the prior austenite grain size, the ferrite and pearlite grain sizes, as well as the size and number of carbide plates. We have subjected specimens of 1020 HRS to a wide variety of heat treatments aimed at obtaining transformed specimens with predictable prior austenite as well as ferrite and pearlite grain sizes. Under the multidisciplinary grant, we shall choose three or four heat treatments

which will provide us with specimens having two different prior austenite grain sizes and two different ferrite and pearlite grain sizes. Both static and dynamic fracture initiation experiments will then be performed on these specimens over a range of temperatures. Based on the results of these tests, and complementary plasticity experiments, we shall calculate values of fracture toughness. Finally, the fractured surfaces and sections through the fractures will be examined in both the optical microscope and the SEM to determine the microscopic source of fracture initiation for this steel. Since most structural steels fall in the hypoeutectoid range our results should be of considerable practical importance.

Technical Reports:

"The Size and Density of Intergranular Carbide Plates in 1020 HRS and Their Role During Brittle Fracture Initiation: A Preliminary Report," Lambropoulos, J.C., Asaro, R. J., Hawley, R. H., and Duffy, J., Brown University Technical Report ARO DAAG29-80-K-0045/1, January 1981.

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